Development Architecture of Remote Laboratory as Learning Solution in Industrial Revolution 4.0 Era

F. Yudi Limpraptono[1], Eko Nurcahyo[1], Ahmad Faisol[2], Masrurotul Ajiza[3], and Dedy Kurnia Sunaryo[3]
[1]Department of Electrical Engineering, National Institute of Technology, Malang, Indonesia
[2]Department of Informatics, National Institute of Technology, Malang, Indonesia
[3]Department of Geodetic Engineering, National Institute of Technology, Malang, Indonesia
Email: { fyudil, ekonur, mzfais, masrurotul_ajiza}@lecturer.itn.ac.id, dekaitn@gmail.com

***Abstract*—Industrial worlds nowadays is encountering a change by entering industrial revolution 4.0 era. This era is also disrupting a lot of human's activities, including science, technology and higher education. In facing industrial revolution 4.0 in education, Indonesian government has tried Cyber University program and the development of 4.0 learning, like distance learning system that is facilitated by SPADA (Indonesian online learning system). SPADA is a program of the Directorate General of Learning and Student Affairs of the Indonesian Ministry of Research, Technology and Higher Education to improve equitable access towards quality learning in higher education. Aggregator of the SPADA Indonesia is used to connect learning management system of higher education and the LMS of SPADA Indonesia. The problem in SPADA and LSM system is generally in a state of having shortcomings in the learning of engineering field, where to achieve learning outcomes, it needs facilities to do laboratory work activity. Using this background, the researchers in this research is integrating between LMS and remote laboratory system. It is expected that the solution of distance learning that integrated with remote laboratory can fulfill all resources needed to achieve learning outcomes education of the engineering field like in conventional learning.**

***Index Terms*—remote laboratory, industrial revolution 4.0, LMS, blended learning, SPADA**

I. Introduction

The emergence of information and communication technology has introduced new features for distance learning and changed it into interactive education called "eLearning", where among teachers, students, and learning materials can do interaction and communication through internet from wherever they are [1]. E-learning is playing an important role in an independent learning activity. E-learning method is giving flexibility and learning autonomy to the students, where they are given flexibilities in choosing place and time to learn [2]. The paradigm shift in education has happened from "faculty centric" learning model or well known as "teacher centered learning" to the "students centric" or "student centered learning" [3].

The concept of E-learning also affected the development of laboratory in the engineering field. Web-based remote laboratory has been promoted in the first creation of internet technology (World Wide Web) and the improvement of computer network started from America in 1970. The effect of information and communication technology has affected the creation of some big education networking and the collaboration of remote laboratories all over the world, like MIT OpenCourseWare, iLab, European Schoolnet and PROLEARN. Now the searching of "remote labs" or "web labs" with Google search will give information of more than 100 laboratories that is much more active through all over the world [4].

Laboratory is an important part in engineering education. Some experiments in labs is helpful to improve students' motivation in learning and to strengthen their understanding about abstract concepts and theories that is taught in lectures. Lab's activities are covering measurement, data collection, analysis, design, and experience using equipments directly [5]. Remote laboratory is a software environment supporting lab's experiments, where the users in distance are possible to communicate and interact with the real measuring and lab's equipments. Remote laboratory is not only offering interactive but also real stimulation, like working in traditional laboratory [4]. The users can access remote laboratory from home or wherever by using internet facility [6]. From the result of reference study, remote laboratory in electrical and mechanical engineering are the most published, like electronic lab, programmable devices (LD and microcontroller), robotics, automation, and mechatronics [4].

The fourth industrial revolution is mostly referred as Industry 4.0 has a holistic influence to almost every aspect of manufacture and other economic sectors, transformation in factory is not only limited to the production system, but also the requirements to the people supporting the transformation itself [7].

It is often forgotten that an innovation is not only coming in a form of investment in new technology, but beyond that it is human resources and education investments in which they can anticipate very quickly technology changing [8]. The importance of experiment based learning in higher education of engineering field

Manuscript received June 26, 2020; revised December 9, 2020.

doi: 10.18178/jiii.8.2.49-53

[9], added by the increasing number of students is encouraging the promotion of remote laboratory that is heading to the use of effective and efficient machine. Moreover, the trouble of time and distance can be solved by maintaining the benefits of research-based learning approach [10].

In facing industrial revolution 4.0 in education, Indonesian government has tried Cyber University program, and the 4.0 learning development, like lectures system of distance learning that is facilitated by SPADA (Indonesian online learning system), and IdREn (Indonesian Research and Education Network). SPADA is a program of the Directorate General of Learning and Student Affairs of the Indonesian Ministry of Research, Technology and Higher Education to improve equitable access towards quality learning in higher education. Aggregator of the Indonesian SPADA is used to connect learning management system (LMS) of higher education and the Indonesian SPADA LMS. Through this aggregator, the registered online lectures data and the activities will be displayed and recorded in Indonesian SPADA. The system of SPADA provides many sources of ICT-based learning, facilities of interaction between tutors and students using various means of interaction (short text message, email, chat, audio/video conference) [11].

The problem in Indonesian SPADA and LMS system is generally in a state of having shortcomings in the learning of engineering field, where to achieve learning outcomes; it needs facilities to do laboratory work activity. Using this background, the researchers in this research is integrating between LMS and remote laboratory system.

This paper is organized as follows: Chapter 2 will discuss about learning management system (Moodle), while chapter 3 will discuss about Indonesian online learning system. Chapter 4 contains of the discussion of integration between remote lab and LMS, and chapter 5 is the conclusion of the conducted research.

II. LMS MOODLE

MOODLE (short for Modular Object-Oriented Dynamic Learning Environment) is a software package provided for internet-based learning activities and websites that use social constructivist pedagogical principles. It is one of the applications of the concepts and mechanisms of teaching and learning that utilize information technology, which is known as the concept of electronic learning or e-learning. Moodle can be used freely as an open source product under the GNU license. It can be installed on any computer and operating system that can run PHP and supports SQL databases.

In the world of e-learning Indonesia, Moodle is better known as the Course Management System or "Learning Management System" (LMS). With a display like a web page in general, Moodle has a feature to present courses (courses), where teachers can upload teaching materials, questions and assignments. Students can log into Moodle then choose the course provided or enrolled for it. Student activities in this Moodle will be monitored by their progress and grades. In Indonesia, it is known that Moodle has been used for high schools, colleges and companies.

III. SPADA INDONESIA

Indonesia online learning system, or well known as SPADA Indonesia (http://spada.ristekdikti.go.id) is one of the programs of the Directorate General of Learning and Student Affairs of the Indonesian Ministry of Research, Technology and Higher Education to improve equitable access towards quality learning in higher education. With its online system, it gives an opportunity to the students of a university to follow a certain quality lecture from different university and the result of the learning can be equally approved by their own university.

SPADA Indonesia is developed to answer some challenges of higher education, like the limited capacity of the university, the low affordability of the university due to uneven distribution, some numbers of university that still do not have qualified education resources, qualified universities that still centered in Java island, the lack of quality and equal service in a university, and the lack of fulfillment guarantee of needs for quality university.

Figure 1. SPADA system [11]

The emergence of information and communication technology (TIC) that is very sophisticated now is offering big potential to answer the challenges stated above. TIC gives an opportunity to conduct networked higher education and online learning. On this basis, SPADA is present as one of the breakthrough of the Directorate General of Learning and Student Affairs of the Indonesian Ministry of Research, Technology and Higher Education to improve skilled sources in higher education.

Aggregator of SPADA Indonesia is used to connect LMS of higher education and LMS of SPADA Indonesia, shown in Fig. 1. Through this aggregator, registered online learning data and the activities can be presented and recorded in SPADA Indonesia. The integration process is conducted by installing plug-in web service and registering it [11].

IV. REMOTE LABORATORY

A. Introduction to the Remote Laboratory

A remote laboratory is a web-integrated system that allows the student to carry out his experiments with real

instruments through a unified interface by a web browser. By providing distance users a way to share resources and tools, it may cause cost reduction and access to some more specialized learning resources that are not available locally. The advantages and disadvantages are further detailed.

Advantages:

1. The students can carry out their experiments with real instruments. So that it allows the student to work from their houses although the physical instruments are in a real laboratory whose door is closed.
2. The teacher can have information about the student's progress.
3. The web server allows the student to work with collaborative tools.
4. Laboratory performance will be better and more efficient because students can use laboratory equipment for 24 hours.
5. A remote laboratory creates autonomous learning, and allows use by handicapped student.

Disadvantages:

1. Every educational organization develops its own solution so it is very difficult to reuse programming code.
2. It is necessary to use a good Internet connection, because data, audio and video are usually going to be transmitted.

B. Structure of Remote Laboratory

The remote laboratory used in this research project is a remote laboratory from previous research and has been published under the title "New Architecture of Remote Laboratories Multiuser Based on Embedded Web Server" [12]. Diagram of the remote lab architecture is shown in Fig. 2. The system consists of web server based on Raspberry Pi as remote lab gateway; two experimental modules; IP camera; and several client side computers.

Web server remote lab gateway contains several software applications such as Apache web server, MySQL database server and a remote lab user management. User management application functions to handle user requests that will access the remote lab and manage all remote lab resources. The main function of the embedded web server is to control the experiment module and become the user interface between the user and experiment modules. Furthermore, embedded web server can send log report to the database server and send a message to the chat application [12].

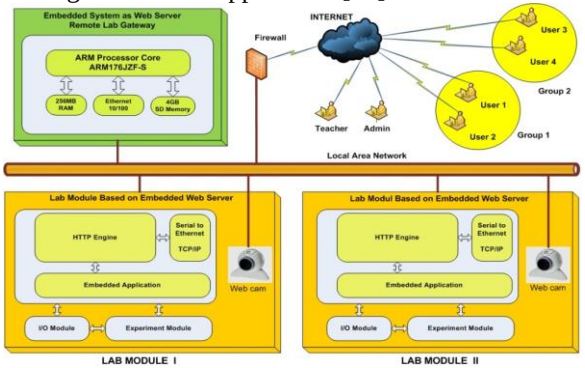

Figure 2. Remote laboratory architecture [12]

V. INTEGRATION OF SPADA, LMS AND REMOTE LABORATORY

Efforts by the Indonesian government to improve equitable access towards quality learning in higher education, the Directorate General of learning and student affairs of the ministry of research, technology and higher education, Indonesia, built an Indonesian online learning system that gave the name SPADA Indonesia. All universities in Indonesia can utilize the SPADA system. The SPADA system as an aggregator serves to connect the LMS spread across universities with the Indonesian SPADA system so that data and online learning activities can be presented and recorded at SPADA Indonesia.

In this research project, not only LMS was integrated with SPADA Indonesia as an aggregator but integration was carried out between LMS and remote laboratory. We are working in the creation of a middleware that allow different remote lab to use the LMS services as user registration, security options, communication tools, etc. Remote laboratory must be an integrated module or service to be used from e-learning solution. This module must manage the laboratory instruments and the results that the students obtain to do their practices. Integration of SPADA, LMS and Remote Laboratory diagram is shown in Fig. 3.

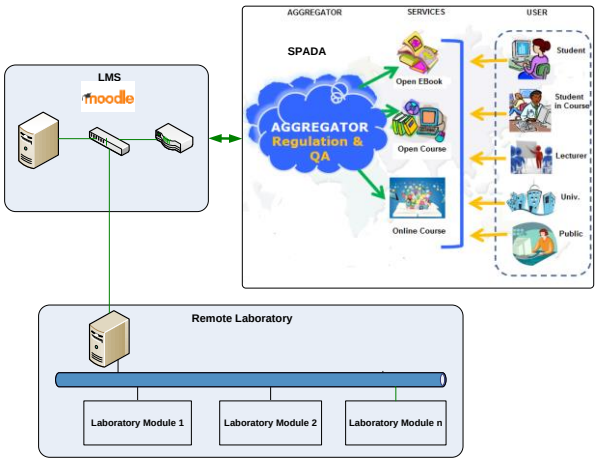

Figure 3. Integration of SPADA, LMS and Remote Lab

The method for integrating the Moodle LMS with SPADA Indonesia is by registering as an online course organizer to the SPADA Indonesia aggregator and integrating the SPADA plugin into the Moodle LMS. The installation of the SPADA Indonesia aggregator plugin is done by downloading the plugin package from *http://spada.ristekdikti.go.id/files/plugin/spada.zip*, then adding AUTH CODE and overwriting the default Moodle course file. Once integrated, the course process can be done through SPADA Indonesia or through Higher Education LMS. The learning process will be recorded, monitored and evaluated through the Indonesian SPADA aggregator system.

The second step is to integrate the Moodle LMS with the remote lab application, by activating the web service on the Moodle LMS so that the remote lab application can access data from the Moodle LMS. Fig. 4. shows a communication diagram between SPADA, Moodle LMS

and Remote Lab. The remote lab application will send a request to the Moodle LMS web service by sending a username and password that has been registered with Moodle. If the login data is correct, Moodle will send a TOKEN. This token can be used to access other data from the Moodle LMS. When students will take part in an experiment, remote lab access from Moodle has obtained a user token to access data from Moodle and access the lab module online.

The remote laboratory will use some of the LMS services, like:

- User administration involves roles, user registration, etc.
- The remote laboratory does not need to create new communications tools, but user can use the LMS's communication tools (email, chats, bulleting board, etc).
- We have to create documents that the students read to carry out their experiments, and also we have to create test to evaluate the students.

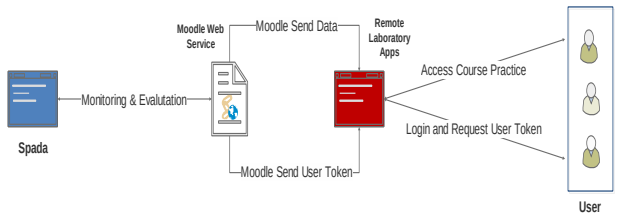

Figure 4. A communication diagram

VI. Conclusion

This paper describes our research project to development architecture of remote laboratory as learning solution in industrial revolution 4.0 era. The architecture development was carried out by integrating the remote laboratory with the LMS Moodle, and the system was integrated with aggregator of SPADA Indonesia. At the time of writing, the research project is still ongoing in the first year of three years. The integration of remote laboratories into the LMS and SPADA systems is the first in Indonesia and expected to contribute to increase SPADA Indonesia's services in providing learning resources to achieve lecture learning outcomes, especially in the field of electrical engineering.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

F. Yudi Limpraptono, Eko Nurcahyo, Ahmad Faisol conducted the research; Masrurotul Ajiza, Dedy Kurnia Sunaryo wrote the paper; all authors had approved the final version.

Acknowledgment

The authors would like to thank to the Indonesian Directorate General of Higher Education, which provided the funds for the research project. The authors also thank to the National Institute of Technology Malang, which support of our research.

References

[1] M. Tawfik, E. Sancristobal, and M. Sergio, "Towards a better deployment of remote laboratories in undergraduate engineering education," *Bilbao: University of Deusto*, 2011.

[2] J. Garcia-Zubia, D. Lopez-de-Ipiña, and P. Orduña, "Evolving towards better architectures for remote laboratories: A practical case," *International Journal of Online Engineering (iJOE)*, vol. 1, no. 2, Aug. 2005.

[3] J. B. Biggs and C. S. Tang, "Society for research into higher education," in *Teaching for Quality Learning at University*, Maidenhead: Mc Graw-Hill: Open University Press, 2011.

[4] L. Gomes and S. Bogosyan, "Current trends in remote laboratories," *IEEE Transactions on Industrial Electronics*, vol. 56, no. 12, pp. 4744 –4756, Dec. 2009.

[5] J. E. Ashby, "The effectiveness of collaborative technologies in remote lab delivery systems," in *Proc. Frontiers in Education Conference, FIE 2008. 38th Annual*, 2008, pp. F4E–7–F4E–12.

[6] J. Garcia-Zubia, U. Hernandez, I. Angulo, P. Orduña, and J. Irurzun, "Acceptance, usability and usefulness of Web Lab-Deusto from the students point of view," *International Journal of Online Engineering (iJOE)*, vol. 5, no. 1, pp. pp. 9–15, Feb. 2009.

[7] J. Grodotzki, T. R. Ortelt, and A. E. Tekkaya, Remote and Virtual Labs for Engineering Education 4.0, Procedia Manufacturing, 2018, pp. 1349-1360.

[8] Essen, "University education report 2020: Higher education for the working world 4.0," Stifterverband für die Deutsche Wissenschaft e.V, 2016.

[9] L. D. Feisel and A. J. Rosa, "The role of the laboratory in undergraduate engineering education," *Journal of Engineering Education*, 2005, pp. 121-130.

[10] J. Garc á-Zub á, R. G. Alves, *et al*., *Using Remote Labs in Education*, Two Little Ducks in Remote Experimentation, Deusto Publicaciones, 2011.

[11] SPADA Indonesia. (August 2019). *Integrasi LMS Perguruan Tinggi ke SPADA Indonesia*. [Online]. Available: http://spada.ristekdikti.go.id

[12] F. Y. Limpraptono, A. A. P. Ratna, and H. Sudibyo, "New architecture of remote laboratories multiuser based on embedded web server," *Int. J. Online Eng.*, vol. 9, no. 6, pp. 4–11, 2013.

F. Yudi Limpraptono received the Bachelor's degree in Electronics from Brawijaya University, Malang, in 1994. His Master degree in Embedded System and Ph.D. degree in Computer Engineering both from the University of Indonesia obtained in 2000 and 2015 respectively. Currently, Dr. Yudi Limpraptono, ST.,MT. is a Lecturer and researcher in Electrical Engineering Department, Faculty of Industrial Technology, National Institute of Technology, Malang, East java, Indonesia. His area of research interest includes Embedded System Applications, Remote Laboratory, Electronic Telecommunication and Green Computing Technology, and member of IEEE since 2010.

Eko Nurcahyo received the Bachelor's and Master degree in Electrical Engineering from National Institute of Technology Malang, obtained in 1987 and 2012 respectively. Currently, Eko Nurcahyo is a head of Diploma of Electrical Engineering, National Institute of Technology Malang. His area of research interest includes power electronic and power management.

Ahmad Faisol received the bachelor's degree from National Institute of Technology Malang and master degree in Computer Engineering from Brawijaya University, obtained in 2008 and 2014 respectively. Currently, Ahmad Faisol is a head of Computer Programming Laboratory Departement of Electrical Engineering, National Institute of Technology Malang. His area of research interest includes information systems, web and mobile programming, and decision support system.

Masrurotul Ajiza received her bachelor's degree from University of Kanjuruhan Malang and Master Degree from University of Islam Malang both in English for Education, obtained in 2005 and 2011 respectively. Now, Ms. Ajiza is a lecturer in Geodetic Engineering, National Institute of Technology Malang. Her area of research interest includes English for engineering and Learning Technology.

Dedy Kurnia Sunaryo received his Bachelor's degree in Geodetic Engineering from National Institute of Technology Malang in 1994. He obtained master degree in Geodetic Engineering from Bandung Institute of Technology in 2000. Currently, Dedy Kurnia Sunaryo, ST, MT. is a Lecturer and researcher in Geodetic Engineering Department, Faculty of Civil Engineering and Regional Planning, National Institute of Technology Malang. His research interest includes Geodatabase Development, Satellite Remote Sensing, Geographic Information System, and Environmental Green Technology. He also active in Indonesian Survey Organization, Indonesian Remote Sensing Society, and help government develop one map policy in Indonesia.